

LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 3

Water and Life



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Overview: The Molecule That Supports All of Life

- Water is the **biological medium** on Earth
- All living organisms require water
- **Most cells are surrounded by water, and cells themselves are about 70–95% water**
- **The abundance of water is the main reason the Earth is habitable**

Fig. 3-1

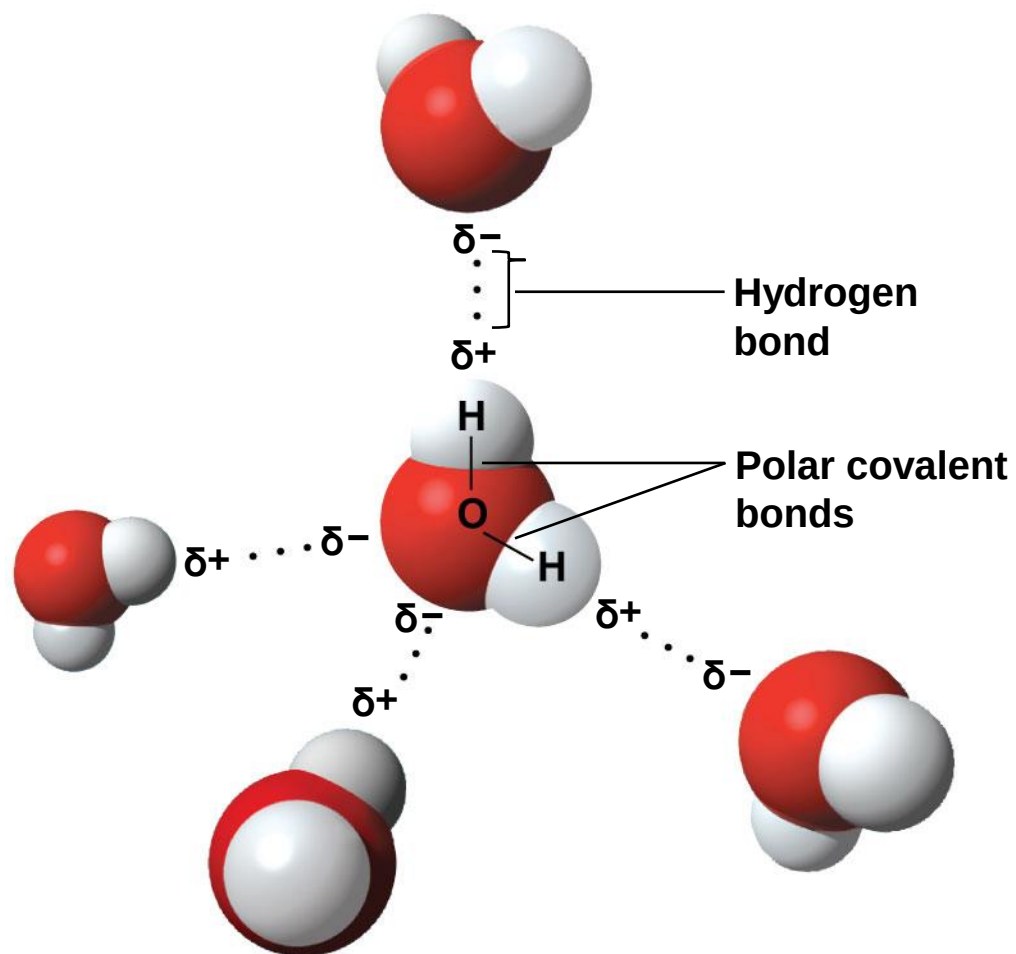


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Concept 3.1: The polarity of water molecules results in hydrogen bonding

- The water molecule is a **polar molecule**: *The opposite ends have opposite charges*
- Polarity allows water molecules to form hydrogen bonds with each other

Figure 3.2



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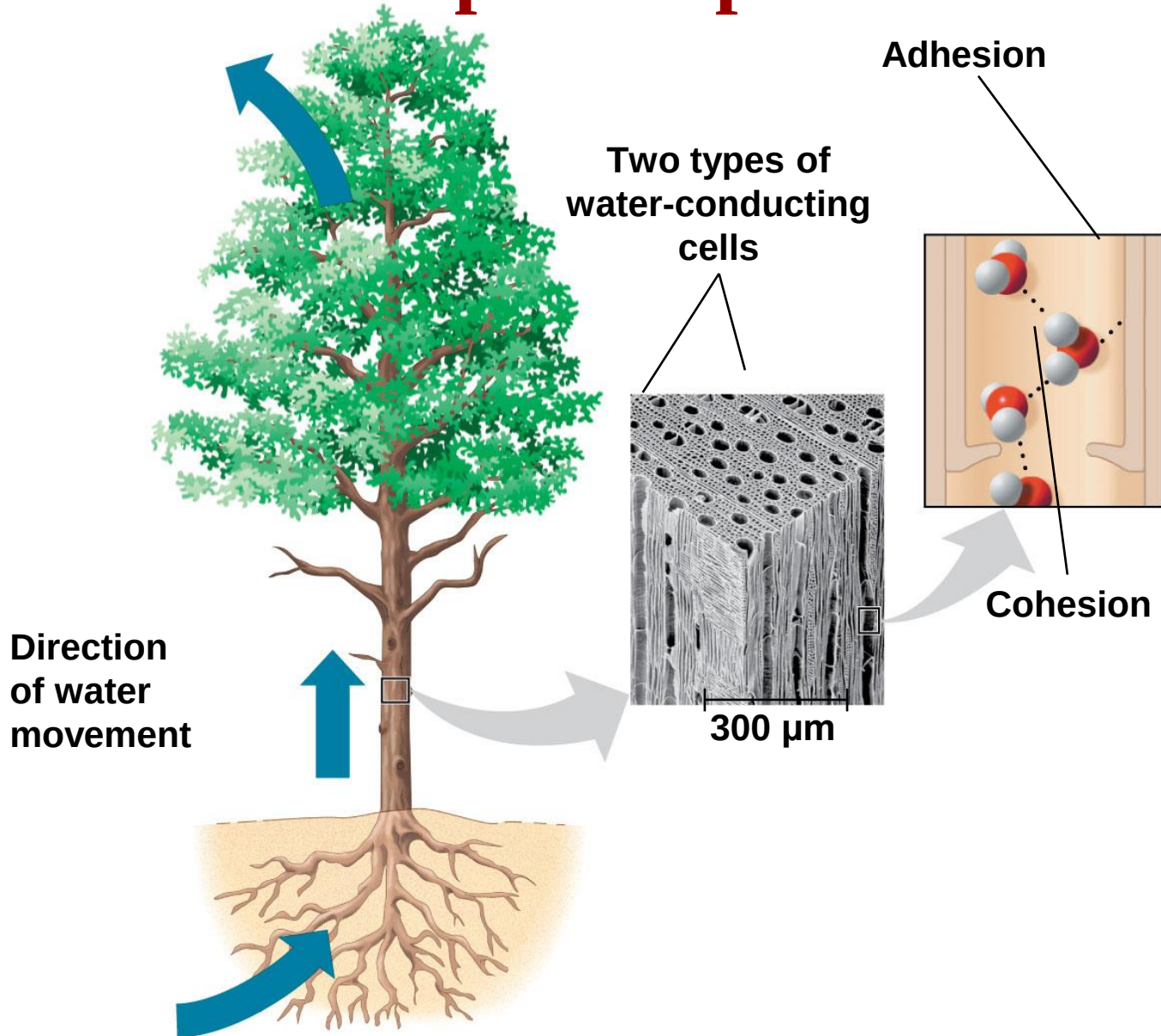
Concept 3.2: **Four emergent properties of water contribute to Earth's fitness for life**

- Four of water's properties that facilitate an environment for life are:
 - **Cohesive behavior**
 - **Ability to moderate temperature**
 - **Expansion upon freezing**
 - **Versatility as a solvent**

Cohesion

- Collectively, hydrogen bonds hold water molecules together, a phenomenon called cohesion
- Cohesion helps the transport of water against gravity in plants
- Adhesion is an attraction between different substances, for example, between water and plant cell walls

Water transport in plants.



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- **Surface tension** is a measure of **how hard it is to break the surface of a liquid**
 - **Surface tension is related to cohesion**

Moderation of Temperature

- Water absorbs heat from warmer air and releases stored heat to cooler air
- Water can absorb or release a large amount of heat with only a slight change in its own temperature

Heat and Temperature (study alone)

- **Kinetic energy** is the energy of motion
- **Heat** is a measure of the *total amount* of kinetic energy due to molecular motion
- **Temperature** measures *the intensity* of heat due to the *average* kinetic energy of molecules

Heat and Temperature (study alone)

- The **Celsius scale** is a measure of temperature using **Celsius degrees ($^{\circ}\text{C}$)**
- A **calorie (cal)** is the amount of heat required to raise the temperature of 1 g of water by 1°C
- The “calories” on food packages are actually kilocalories (kcal), where $1 \text{ kcal} = 1,000 \text{ cal}$
- **The joule (J)** is another unit of energy where $1 \text{ J} = 0.239 \text{ cal}$, or $1 \text{ cal} = 4.184 \text{ J}$

Water's High Specific Heat

- The **specific heat** of a substance is the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1°C
- The **specific heat of water** is **1 cal/g/°C**
- Water resists changing its temperature because of its high specific heat

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- **Water's high specific heat can be traced to hydrogen bonding**
 - Heat is absorbed when hydrogen bonds break
 - Heat is released when hydrogen bonds form
 - **The high specific heat of water minimizes temperature fluctuations to within limits that permit life**

Evaporative Cooling

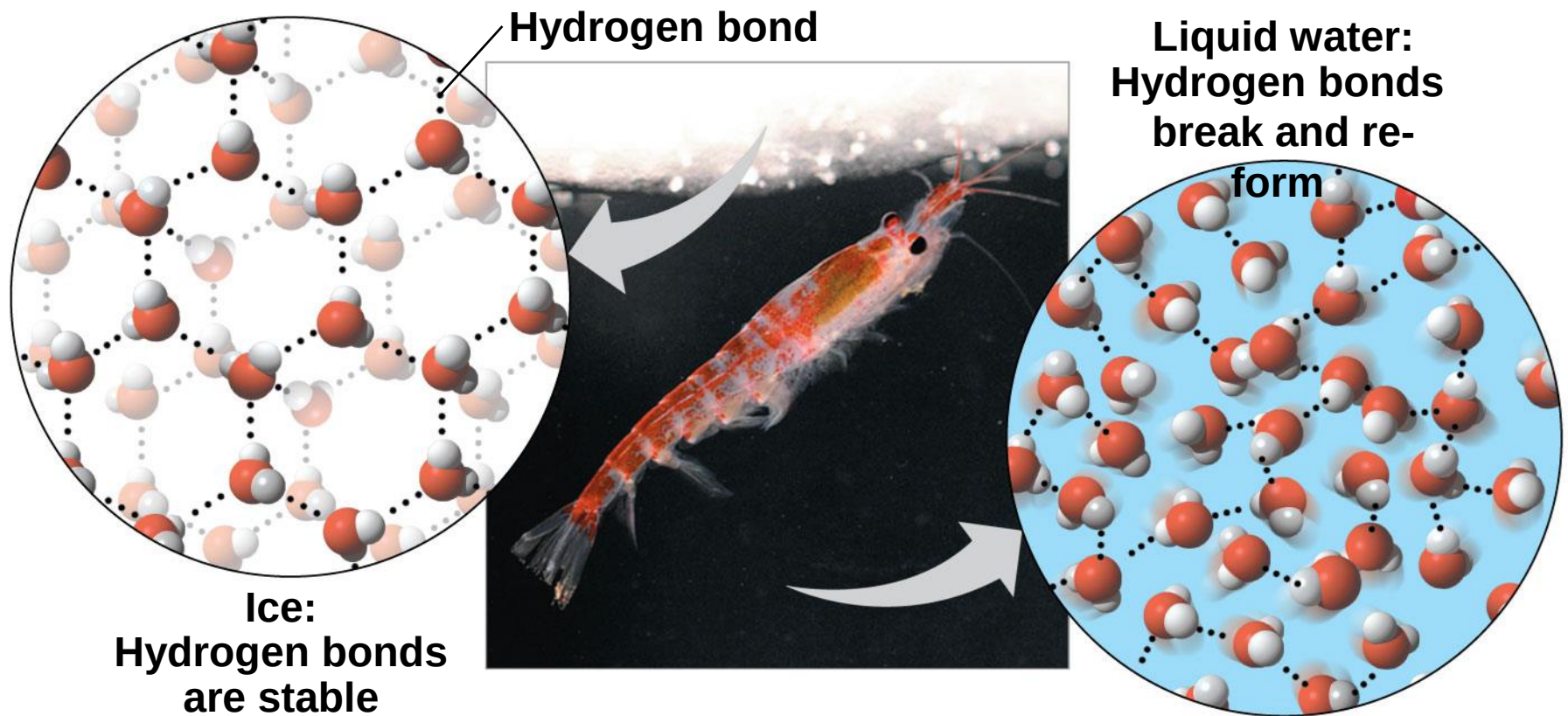
- ***Evaporation*** is transformation of a substance from liquid to gas
- **Heat of vaporization** is the heat a liquid must absorb for 1 g to be converted to gas
- As a liquid evaporates, its remaining surface cools, a process called

evaporative cooling

Insulation of Bodies of Water by Floating Ice

- **Ice floats in liquid water** because **hydrogen bonds** in ice are more “**ordered,**” making ice less dense
- **Water reaches its greatest density at 4°C**
- If ice sank, all bodies of water would eventually freeze solid, making life impossible on Earth

Figure 3.6



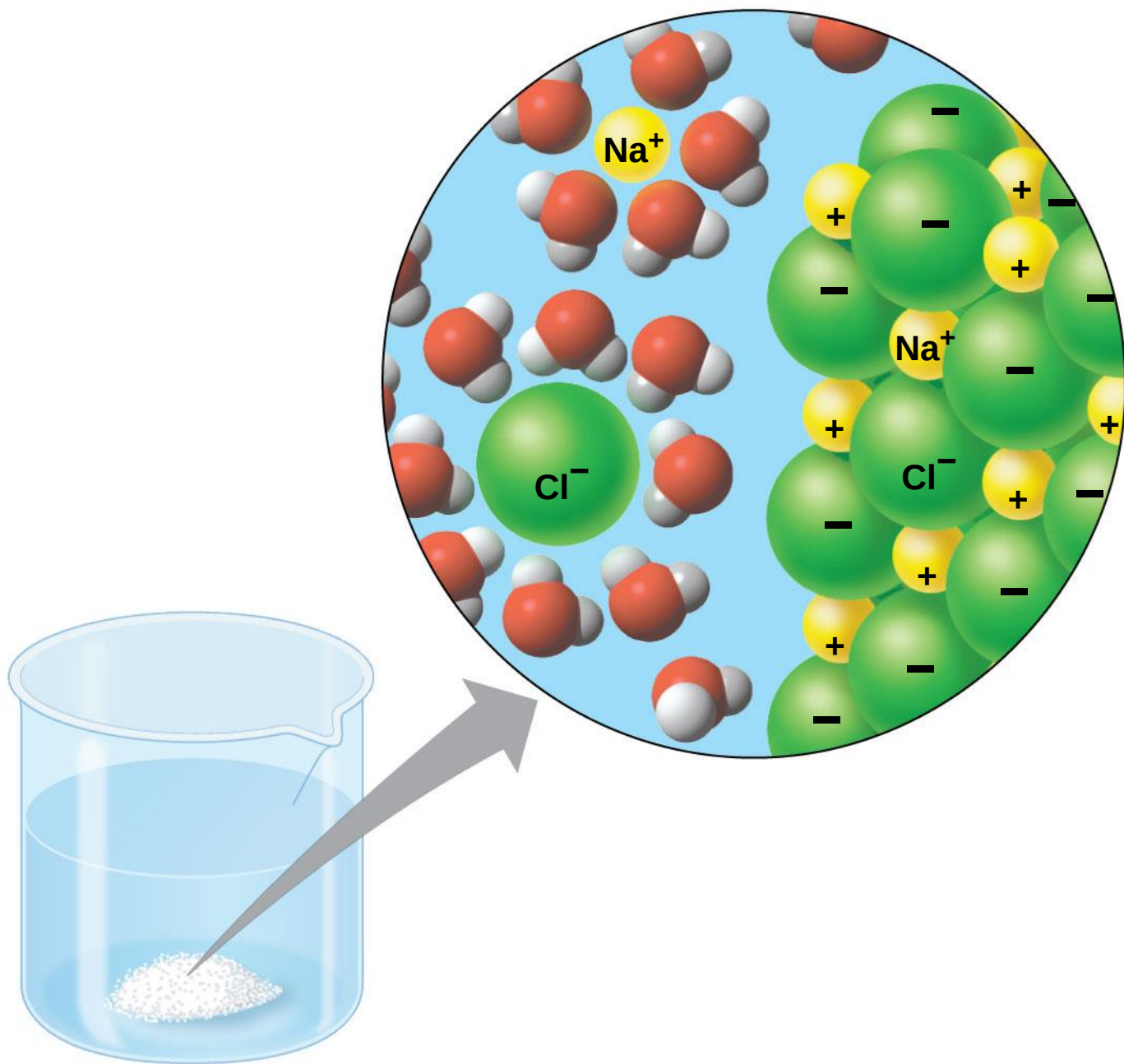
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Water: The Solvent of Life

- A **solution** is a liquid that is a homogeneous mixture of substances
- A **solvent** is the dissolving agent of a solution
- The **solute** is the substance that is dissolved
- An **aqueous solution** is one in which water is the solvent

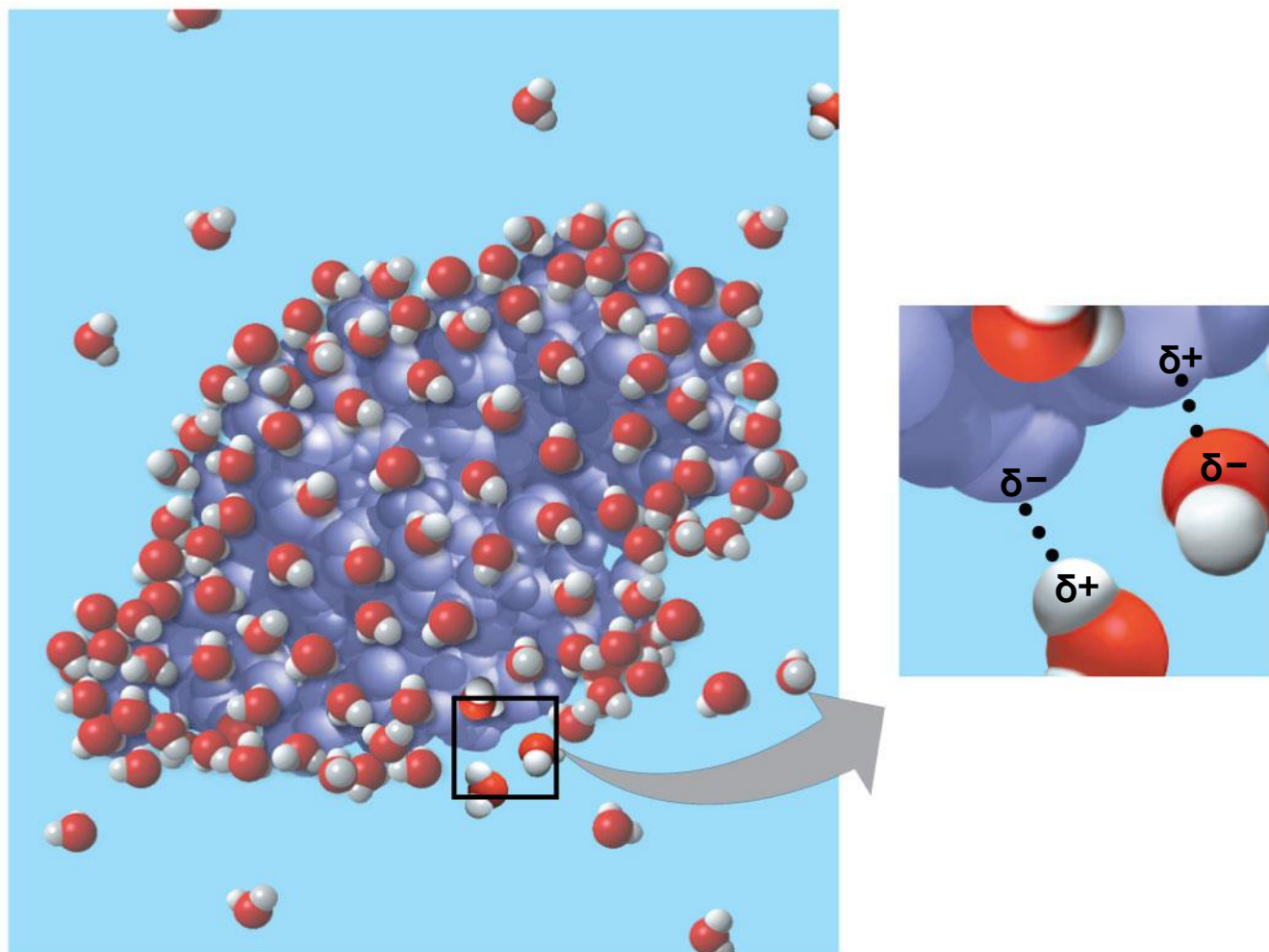
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- Water is a **versatile solvent** **due to**
its polarity, which allows it to
form hydrogen bonds easily
 - When an ionic compound is dissolved in water,
each ion is surrounded by a sphere of water
molecules called **a hydration shell**

Figure 3.7



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- **Water can also dissolve compounds made of nonionic polar molecules**
 - **Even large polar molecules such as proteins can dissolve in water if they have ionic and polar regions**

Figure 3.8



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Hydrophilic and Hydrophobic Substances

- A **hydrophilic** substance is one that has an affinity for water
- A **hydrophobic** substance is one that does not have an affinity for water
- **Oil molecules** are **hydrophobic** because they have relatively nonpolar bonds
- A **colloid** is a stable suspension of fine particles in a liquid

***Solute Concentration** in Aqueous Solutions*

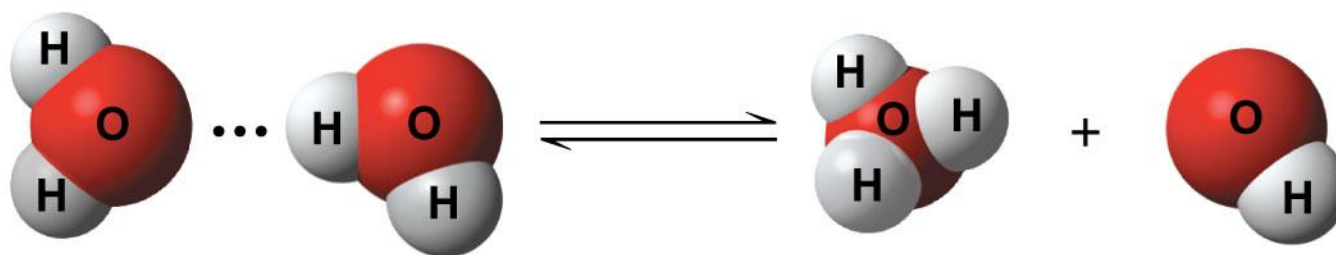
- Most biochemical reactions occur in water
- Chemical reactions **depend on collisions** of molecules and therefore on **the concentration of solutes in an aqueous solution**

- **Molecular mass** *is the sum of all masses of all atoms in a molecule*
- Numbers of molecules are usually measured in **moles**, where **1 mole (mol) = 6.02×10^{23} molecules**
- **Avogadro's number** and the unit ***dalton*** were defined such that **6.02×10^{23} daltons = 1 g**
- **Molarity (M)** *is the number of moles of solute per liter of solution*

Concept 3.3: **Acidic** and **basic** conditions affect living organisms

- The hydrogen atom in water molecules may leave its electron behind and transferred as **a proton**, or **hydrogen ion (H^+)**
- Water molecules may lose the proton = **hydroxide ion (OH^-) is formed**

- **Water is in a state of dynamic equilibrium in which water molecules dissociate at the same rate at which they are being reformed**



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Effects of Changes in pH

- **Adding** certain solutes, called **acids and bases**, modifies the concentrations of H^+ and OH^-
- Biologists use something called the **pH scale** to describe whether a solution is acidic or basic (the opposite of acidic)

Acids and Bases

- An **acid** is any substance that increases the H^+ concentration of a solution
- A **base** is any substance that **reduces** the H^+ concentration of a solution

The pH Scale

- In any aqueous solution at 25°C the product of H^+ and OH^- is constant and can be written as

$$[\text{H}^+][\text{OH}^-] = 10^{-14}$$

- The **pH** of a solution is defined by the **negative logarithm of H^+ concentration**, written as

$$\text{pH} = -\log [\text{H}^+]$$

- For a neutral aqueous solution

$$[\text{H}^+] \text{ is } 10^{-7} = -(-7) = 7$$

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- **Acidic solutions have pH values less than 7**
 - **Basic solutions have pH values greater than 7**
 - **Most biological fluids have pH values in the range of 6 to 8**

Figure 3.10

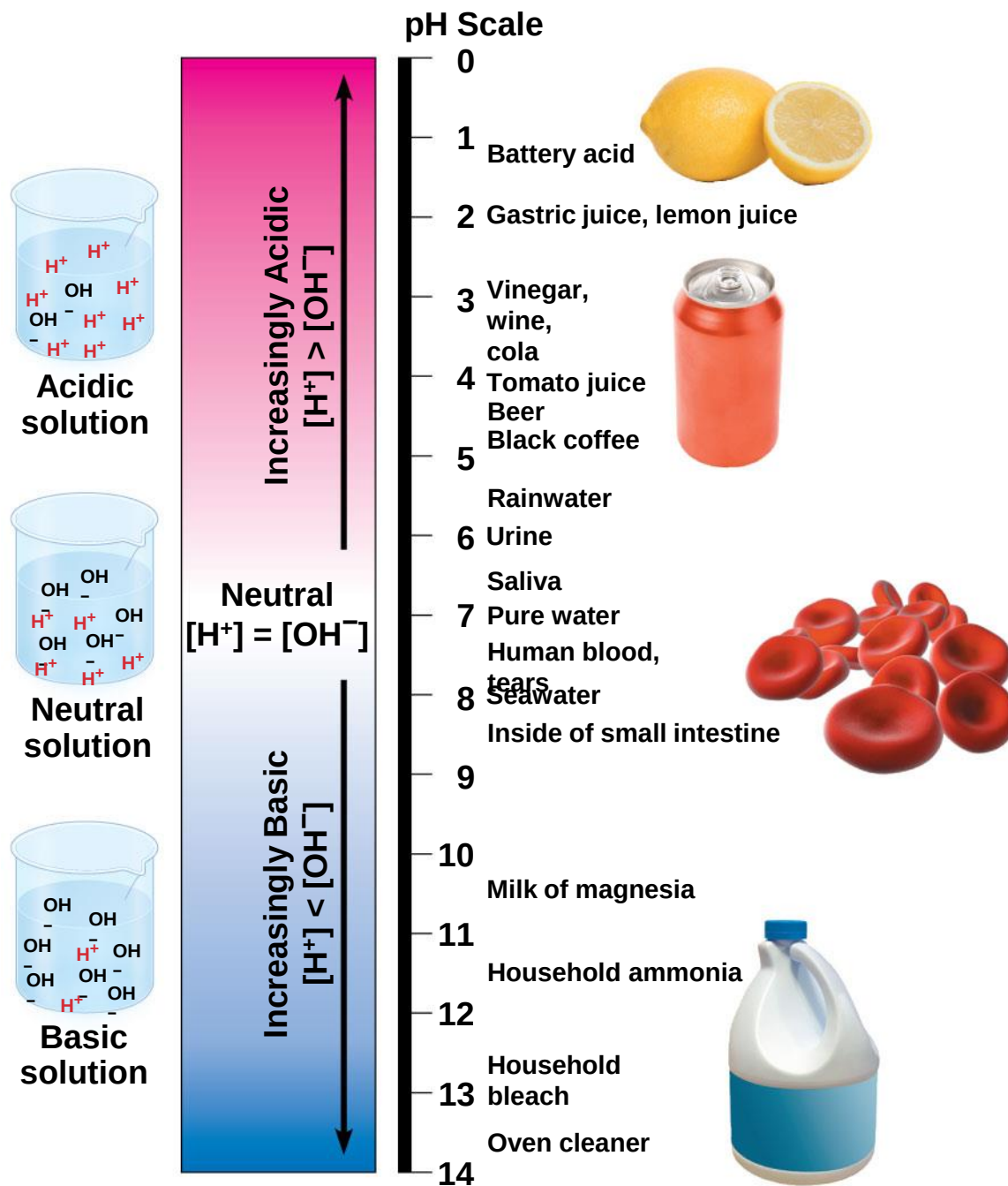


Figure 3.10a



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Buffers

- The internal pH of most living cells must remain close to pH 7
- **Buffers** are substances that *minimize* changes in concentrations of H^+ and OH^- in a solution
- Buffers are made either of **weak acid + its conjugate base** or **weak base + its conjugate acid**